Nucleon - Nucleon Interaction with One - Pion Exchange and Instanton Induced Interaction

C. S. Vanamali* and K. B. Vijaya Kumar†
Department of Physics, Mangalore University, Mangalagangotri, Mangalore - 57499, India

Introduction

The N-N interaction is conventionally explained by the exchange of various mesons [1, 2]. With the advent of QCD, and its acceptance as the theory of strong interaction, attempts have been made since 1980's to explain the N-N interaction from QCD[3].

The basic aim of the present investigation is to make a detailed study of the contribution of the One - Gluon Exchange Potential (OGEP), Instanton Induced Interaction (III) and One - Pion Exchange Potential (OPEP) to the N-N adiabatic potential to the $^1S_0$ and $^3S_1$ states in the framework of Non - Relativisic Quark Model (NRQM) using the Resonating Group Method (RGM).

Theoretical Model

The full Hamiltonian used in the investigation is[3],

$$H = K + V_{int} + V_{Conf} - K_{CM} \qquad (1)$$

where K is the kinetic energy, V_{int} is the interaction potential term and V_{Conf} is the harmonic confinement potential and K_{CM} is the kinetic energy of the centre of mass. The interaction potential includes OGEP, OPEP and III. The III potential in SU(2) NRQM is given by

$$V_{III} = -\frac{1}{2} W \sum_{i<j} [\frac{16}{15} + \frac{2}{5} \boldsymbol{\lambda}_i . \boldsymbol{\lambda}_j + \frac{1}{10} \boldsymbol{\sigma}_i . \boldsymbol{\sigma}_j \boldsymbol{\lambda}_i . \boldsymbol{\lambda}_j] \qquad (2)$$

In the above expressions, $\boldsymbol{\lambda}_i$ and $\boldsymbol{\lambda}_j$ are the generators of the color SU(3) group for the i^{th} and the j^{th} quark, σ_i is the Pauli spin operator W is the strength of III potential and a_c is the confinement strength[4].

Results and Discussion

The parameters used in the model are listed in table I.

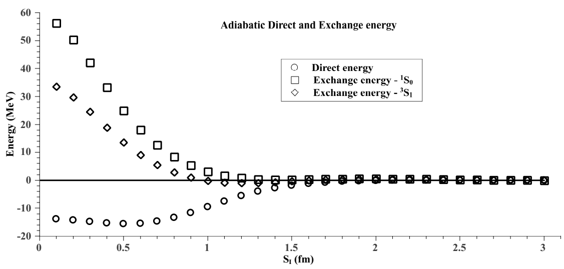

FIG. 1: Adiabatic direct and exchange potentials.

Fig. 1 is a plot of the direct and exchange parts of the Hamiltonian in the adiabatic limit. The exchange part of the potentials of $^1S_0$ and $^3S_1$ states are repulsive in the short range. The exchange potential of the $^1S_0$ state is completely repulsive and that of the $^3S_1$ state shows a small attraction in the intermediate range. There is a substantial repulsive contribution to the adiabatic potential at short range both to the singlet and triplet S states from the color magnetic exchange terms which is consistent with the established results [3, 5, 6]. It should be noted that the color electric term does not contribute to the N-N interaction. Since the radial matrix elements are the same for

*Electronic address: vanamalishastry@gmail.com
†Electronic address: kbvijayakumar@yahoo.com

b (fm)	α_S	W (MeV fm^3)	a_c (MeV fm^{-2})	m_q (MeV)	m_π (MeV)	f_q^2
0.6	0.713	67.67	40.5	300.0	140.0	12.6

TABLE I: List of parameters

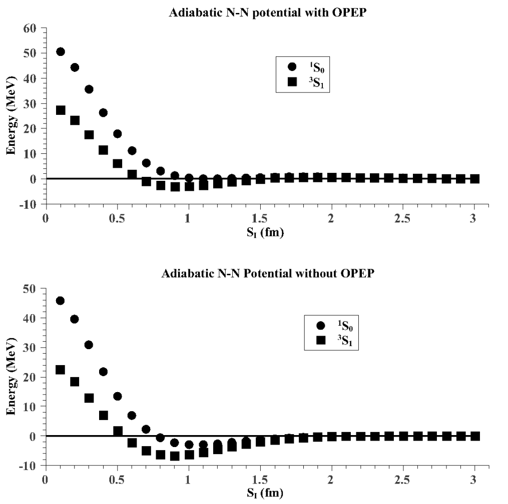

FIG. 2: Adiabatic potential for the singlet and triplet states.

$2(0s)^3$ configuration and for the $(0S)^6$ configuration, the energy difference between $2(0s)^3$ and $(0S)^6$ configuration must come from the expectation value of $\boldsymbol{\lambda}_i.\lambda_j$. But, the expectation value of the $\boldsymbol{\lambda}_i.\lambda_j$ depends only on the number of quarks. Hence, the color electric elements of the OGEP, III and the confinement term do not contribute N-N adiabatic potential. For the color magnetic part the expectation value of $\boldsymbol{\lambda}_i.\lambda_j\sigma_i.\sigma_j$ for the $2(0s)^3$ configuration and for the $(0S)^6$ configuration does not vanish and the color magnetic part provides short range repulsion[3].

The first term in the III interaction (Eq. (2)) due to the antisymmetrization operator gives direct and exchange interaction and corresponds to the color singlet exchange. The adiabatic potential due to the color singlet is attractive in the short range. The entire result of the work is summarized in Fig. 2 which gives the plot of the adiabatic N-N potential with and without OPEP. In the presence of OPEP, attraction in the intermediate range for $^1S_0$ state vanishes. The short range repulsion is larger for singlet state than the triplet state. This difference is entirely due to the color magnetic part of the OGEP and III.

References

[1] A. de Rujula, H. Georgi and S. L. Glashow, Phys. Rev. D **12**, 147 (1975).
[2] R. Machleidt, K. Holinde and Ch. Elster, Phys. Rep. **149**, 1 (1987).
[3] K. Shimizu, Rep. Prog. Phys. **52**, 1 (1989).
[4] M. Oka and S. Takeuchi, Phys. Rev. Lett. **63**, 1780 (1989)
[5] F. Myhrer and J. Wroldnen, Rev. Mod. Phys. **60**, 629 (1988).
[6] A. Valcarce, A. Buchmann, F. Fernandez and A. Faessler, Phys.Rev.C **50**, 2246 (1994).